E. Blucher, M. Jaski, S. Redaelli, Monday 2 November 2015

Mu2E Review

Has the team established to a reasonable level of confidence that their technique will achieve the 10^{-10} level of extinction required by the experiment?

- The reviewers were impressed by the quality of the presentations and by the amount of work performed. The speakers presented their results in a clear and complete way.
- The cleaning of the out-of-time particles relies (1) on the knowledge from simulations of the longitudinal distribution of particles in the delivery ring (DR), (2) on a resonant AC dipole that kicks in time the particles outside the main 1.7 μs pulse, and (3) on a collimation system in the M4 transfer line.
- The reviewers agree that the proposed extinction solution seems adequate to fulfill the design specification. However, there are some comments and suggested checks.
- The reviewers note that the evaluation of the extinction system performance is based on simulations that are performed for nominal parameters of the accelerator chain. They would therefore like to point out that, even if the performance results as presented seem adequate to fulfil the 10^{-10} extinction specification, some additional checks in simulations should be done to assess better the robustness of the proposed solution in the presence of unavoidable imperfections.
- In particular, it was noted that the extinction performance for particles in the range between +/-125ns and +/-225ns relies heavily on a nominal performance of the accelerator chain upstream of the M4 line during complex RF manipulations of the beams. While well above +/-225ns it seems clear that the kick provided by the AC dipole shall be sufficient to dispose of possible out-of-time particles, below this time the equivalent kicks do not yet provide fully efficient cleaning. Differences of RF performance might therefore change the conclusions that were presented. To what level can we rely on the predictions of nominal RF performance presented?
- It is therefore recommended to setup simulations with realistic errors and estimate better the impact on extinction efficiency from over-populated longitudinal tails, or out-of-bucket particles, in the DR.
- It is also suggested to simulate the cleaning performance of the collimation system in the presence of collimator alignment errors in order to exclude that the particles impinging on the collimators with grazing impacts, or intercepting only a reduced length of the tungsten jaws, might be collimated with reduced efficiency than what was

presented. It should also be evaluated if additional collimators downstream, both in the horizontal and in the vertical planes, shall be envisaged to improve the performance.

- The reviewers were presented with the requirements of the collimation system as follows: (1) clean the tails of the extracted beam from the DR (slow resonant extraction); (2) clean of large-divergence particles at the AC dipole; (3) absorb the out-of-time particles kicked by the AC dipole. The collimation system fulfills these roles with three horizontal collimators and is evaluated only for the scope presented.
- Detailed calculations of transfer line aperture and losses were not presented; therefore it was not possible to comment on the statement that no vertical collimation is required.

Comments on the budget:

- It was clarified before the start of the review that evaluation of budgets was not part of the scope of the review. Indeed, no budget figures were presented.
  In answer to the question 4, however, the reviewers would like to comment that the collimation system as presented (1m long tungsten jaws) seems possibly over designed. One might reduce the collimator cost by optimizing the parameters through new simulations.

Does the technical design for the AC dipole system appear feasible and effective? YES.

Findings

1. For the dipole magnet prototype the following was achieved
   a. 300 kHz: 335 Gauss peak-to-peak at 319 A peak-to-peak
   b. 5.1 MHz: 22.3 Gauss peak-to-peak at 20.3 A peak-to-peak
   c. Required 162.11 Gauss peak @ 300 kHz
   d. Required 13.9 Gauss peak @ 4.5 MHz
2. A perfect sine wave for the field is adequate.
3. One of the requirements is 13.9 Gauss peak @ 4.5 MHz but the prototype was tested at 5.1 MHz. A design change relaxed the requirement from 5.1 MHz to 4.5 MHz. This change is expected to make the field easier to achieve.
4. The prototype is ½ m long.
5. The prototype water had a 1-2 C temperature rise at 1 gpm.

6. Field Quality
    a. The sensitivity to field uniformity is dictated by the requirement that we not significantly degrade the angular distribution integrated field within +-10% of nominal over the central 80% of the gap would be negligible based on this criterion.
7. Cooling of the final magnet contains six zones. Connecting these zones in series is expected to work with an adequate temperature rise. Parallel connections are optional if further cooling is desired.
8. One of the ferrite blocks was over heating in the prototype. This was due to poor contact with the cooling tube. In the final magnet each ferrite block will have its own clamp which will eliminate this issue.
9. No presentation on magnetic field analysis was given.
10. The final gap has been changed from 12 mm to 18 mm. Further testing of this new gap will be done on the first magnet built.

Comments

1. We feel that the experience of the FNAL power supplies group is strong. The review committee experience in power supplies is weak and therefore will not be able to review the power supplies.
2. One part of the vacuum chamber shows sheet metal being welded to a block. A weld relief should be machined in the block to achieve a weld that is easier to complete.

Findings 1 through 8 were not given in the presentations and were available on request. Consider including these subjects in future presentations.

Recommendation

The committee recommends building a 1 m, 18 mm gap prototype magnet.

Will the proposed Target Monitor be able to measure extinction at least to the 10^{-10} level with the specified number of protons on target?

Findings

1. Measurement of the required extinction level (10^{-10}) is critical to the success of the Mu2e experiment.

2. The goal of the extinction monitoring system is to have a sensitivity to extinction of 10^{-10} integrating over a few hours (~6E16 protons on target).
3. The target monitor has two main components:
    a. A filter composed of two collimators and a permanent dipole magnet, which transports 4.2 GeV/c protons and pions from the target to the extinction detector.
    b. A detector consisting of 8 pixel planes, 4 upstream and 4 downstream of a permanent dipole magnet. There is a muon range stack behind the spectrometer.

Comments

1. Based on the presentations during the review, including simulations of background levels, the proposed target monitor should be able to measure the required extinction level with ~6E16 protons on target.
2. An elegant design for the positioning and mounting of all components was presented. Detailed alignment procedures for the filter components must still be developed in collaboration with the FNAL Survey Group. Installation of the upstream collimator with the hoist in the center and tilting while sliding in the opening was presented. Safe working procedures should be used when performing this task.
3. The spectrometer with pixel tracker should safely achieve the performance required for the extinction measurement. The pixel tracker takes excellent advantage of the huge R&D investment for the ATLAS experiment.
4. The muon range stack, while not critical to the extinction measurement if backgrounds are as low as expected, will provide important information if there are unanticipated backgrounds. It would be interesting to try to establish the true background level in the target monitor in situ.
5. The DAQ design for the target monitor is based on MicroTCA, which seems appropriate for this scale of project. The DAQ plan should easily satisfy the readout requirements. They have already demonstrated readout of the ATLAS FE-14b chip using prototype hardware.

Recommendation

The committee recommends the early development of a commissioning plan for the full extinction and monitoring system.